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(54) Abstract Title
Analysis or disposal of surface adherents

(57) A non-contacting method for removing substances adhered to a surface and either disposing of them or detecting and analysing them, involves a pressure chamber 9 supplied continuously with a clean gas through an inlet port 14. The gas escapes from the chamber through an annular orifice 10 thereby producing an annular wall jet 8 which when directed onto a surface 2 will flow along it with flow velocity components 16 directed radially inwards entraining removable substances from the surface 2. Opposing radial flow components 16 will on approach be forced away from the surface creating an axi-symmetric flow 17 away from the surface, enabling entrained substances to be transported from the surface 2 to a region within an exhaust port 18 isolated from higher pressure surrounding gas where transported substances may be detected and analysed prior to exhausting through an outlet pipe 19, or simply disposed of.

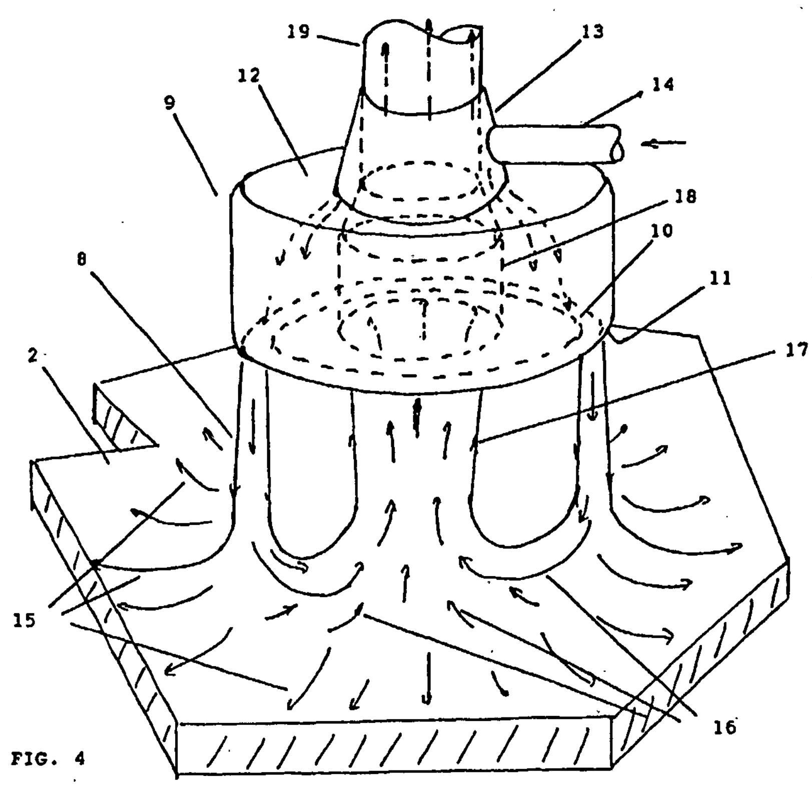

FIG. 4

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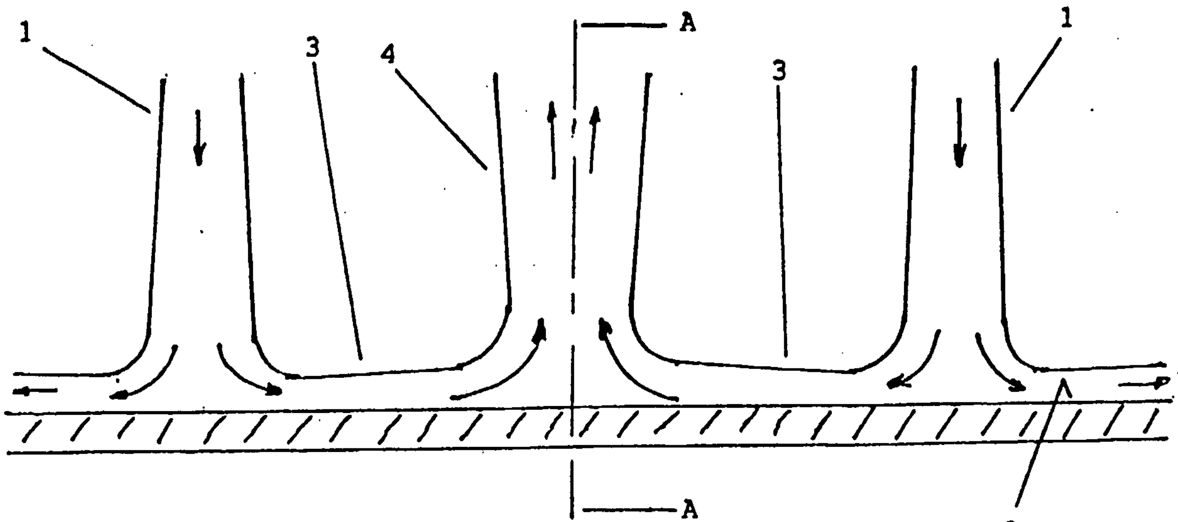

FIG. 1

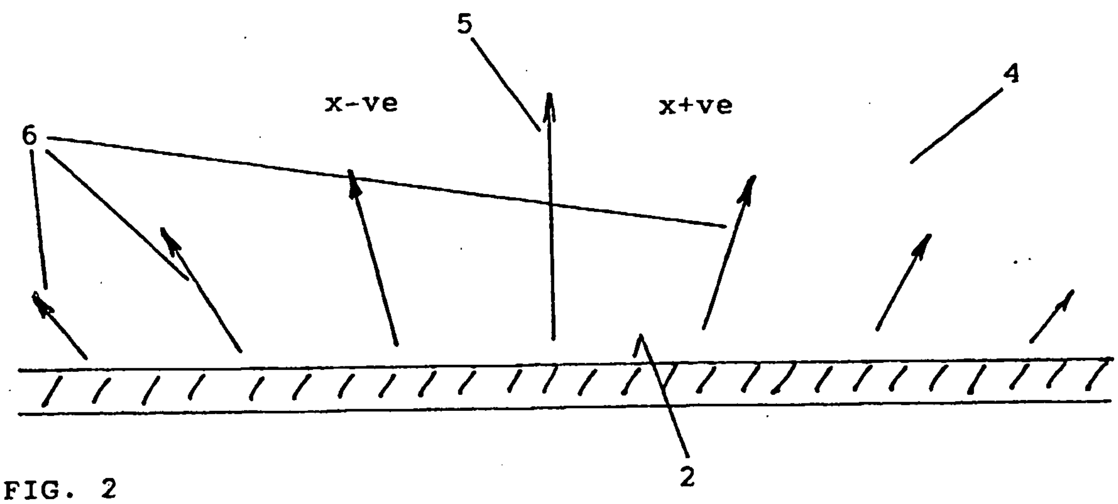

FIG. 2

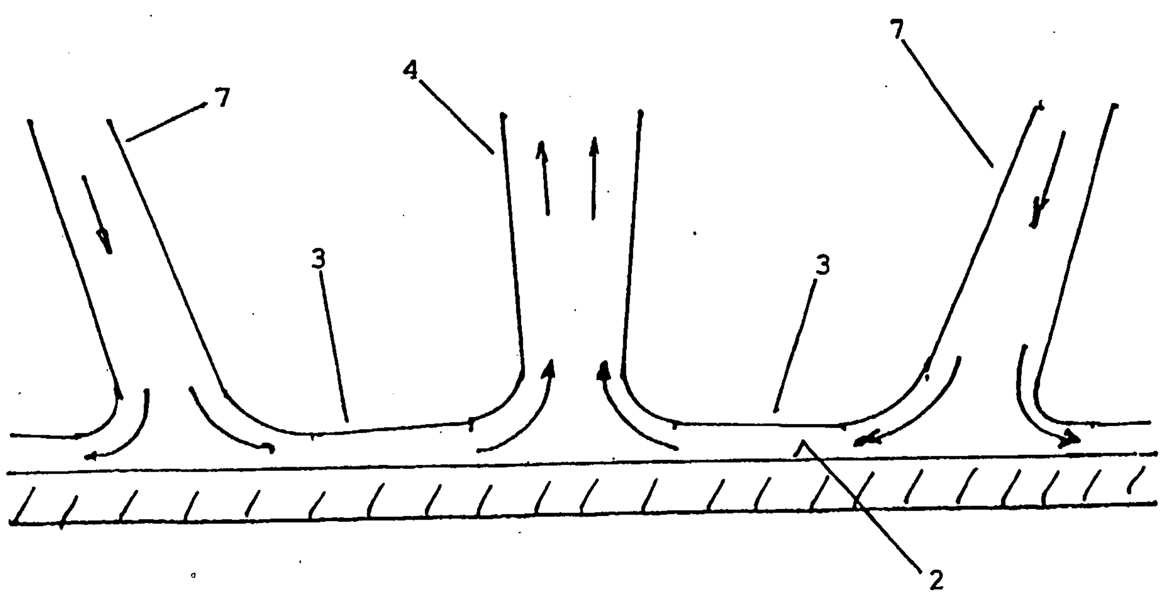

FIG. 3

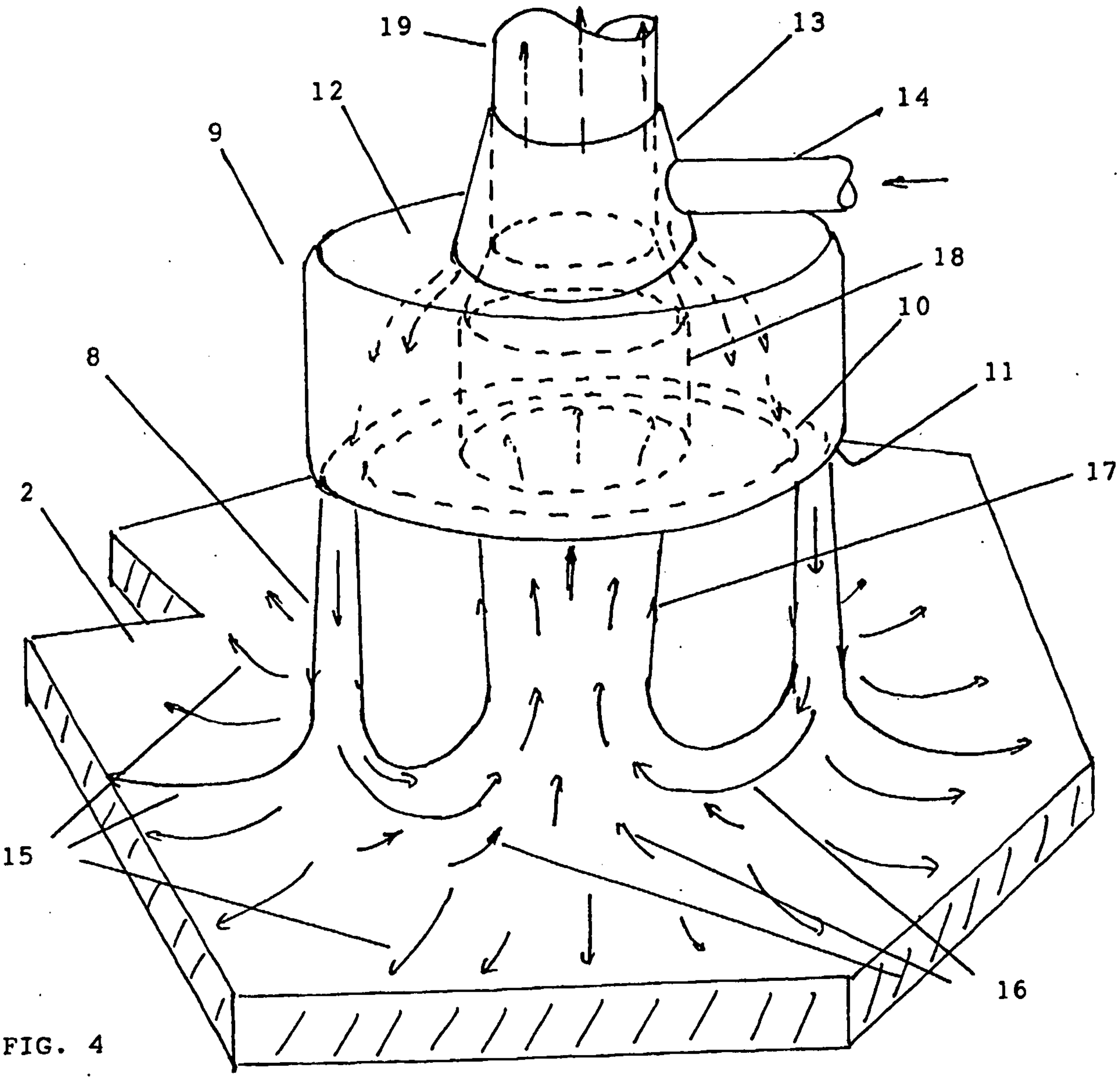

FIG. 4

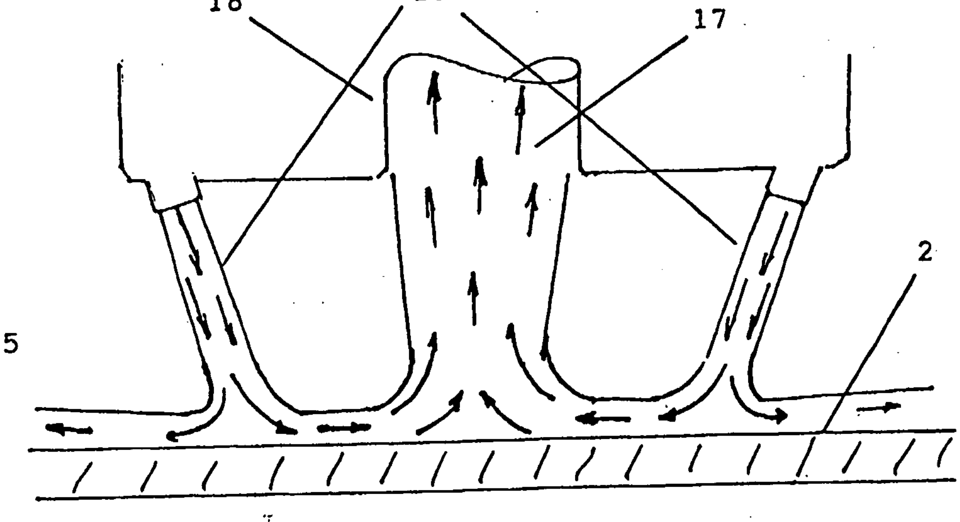

FIG. 5

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ANALYSIS OR DISPOSAL OF SURFACE ADHERENTS

This invention relates to a method and apparatus for remote monitoring of surfaces to detect and characterise removable substances freely or loosely bound to surfaces. Numerous non-contacting methods exist including optical infrared or ultraviolet based systems which detect optical reflections from radiation directed onto the surface. Such reflections may possess information relating to the properties of the surface such as its topology, its degree of specularity, its chemical composition and its moisture content or state of dryness. Methods for monitoring the above properties and others may exploit for example photoluminescence spectrophotometry and scanning laser beams. If the surface possesses solids or liquid substances forming contaminants for example such substances may modify the underlying surface radiation reflection characteristics unless the substances occur in small or trace amounts in which case their reflection characteristics may be dominated by the influence of other surface properties. If removable substances possess detectable properties significantly different from the surface on which they reside or to which they are adhered they may be detectable by absorption of incident radiation at specific wavelengths (which for water are in the infrared) even if existing in trace amounts. Similarly certain substances may be caused to fluoresce when irradiated by ultraviolet light and be detectable in small amounts. However such measurements are only applicable and specific to certain substances and cannot be generally applied to detect all adhered substances irrespective of their physical or chemical nature particularly if such substances are present only in trace quantities.

It is the object of this invention to provide a means for removing substances adhered to or freely bound to a surface and transporting said substances or a proportion of them to a location away from said surface for the purpose of either disposing of said substances if these were unwanted or detecting and analysing them using one of a number of analytical methods and thereby eliminating the influence of residual surface properties on substance detectability.

Fothergill I R - PhD Thesis, University of Aston in Birmingham 1974 - developed a gas jet flow configuration for non-contacting temperature measurement which enabled heat transfer between a surface and one or more wall jets generated from respective free jets to be monitored at a location away from the surface by causing opposing wall jet flow vectors to interact on approach and thereby forcing the interacting wall jets to move away from the surface and effectively create a retro-flow configuration. For convenience this retro flow configuration will be called a Wis jet where Wis is an acronym standing for Wall jet Impingement Synthesis.

In this document frequent use is made of the word 'analysis' and 'characterisation' but it will be understood that for the purposes of this document these words may be considered interchangable.

According to one aspect of this invention there is provided a method for removing for disposal or detection and characterisation free or loosely adhered substances on a surface involving the steps of directing one or more free jets onto the surface to create respective

wall jets flowing along the surface in order to entrain removable substances into the wall jet or jets and thereby transport them away from the surface by means of a flow configuration which moves away from the surface as a result of the interaction of opposing wall jet flow velocity components said substances being transported to a region away from the surface for disposal or detection and characterisation this latter involving one of a number of possible sensors appropriate to the liberated substances nature.

In the current invention the Wis jet performs a totally different function to that involved in temperature measurement in the that interaction with the surface along which wall jets flow prior to flowing away as a Wis jet are mechanical rather than thermal. This process involves viscous drag forces and high levels of turbulence characteristic of all developed jet configurations both of which contribute to the removal and transportation of substances from the surface. It will be noted that in the case of temperature measurement only heat transfer processes are involved in which case precautions are required to minimise heat loss from free jets and Wis jets to the environment these losses occurring predominantly through turbulent interaction with environmental air or the relevant gas. In the current invention no such considerations are necessary and indeed different properties of jet flow become significant. In particular to remove some strongly adhered substances high free jet and wall jet flow rates may be required to create the necessary high shear stresses or viscous drag forces in the contacting boundary layer regions. The corresponding high levels of turbulence in the outer boundary layers will prevent accumulation of liberated substances and thus promote the transportation of these substances via the Wis jet for analysis or disposal as appropriate.

According to a second aspect of this invention there is provided apparatus comprising a free jet generating facility for producing and directing one or more free jets onto a surface to form corresponding wall jets on the surface in order to liberate free or loosely adhered substances from the surface by viscous drag forces associated with the wall jets inner boundary layers and thereby transport said liberated substances entrained into a wall jet or jets to a region away from the surface by means of a jet flow configuration moving away from the surface as a result of interaction of opposing wall jet flow components said region possessing means for either collection and disposal of entrained substances or detection and characterisation using appropriate sensors.

In the current invention the facility for detecting and characterising liberated substances is located away from the surface and supplied with air borne sustances transported by the Wis jet from the surface. Substances to be monitored may exist in the solid, liquid, gas or vapour phase whilst under analysis but prior to liberation from the surface the substances may exist in the solid phase possibly dispersed continuously over the surface or in descrete areas. Alternatively they may exist in the liquid phase again dispersed over extended areas or locally in smaller descrete areas. In some cases mixed solid and liquid phases may exist. Substances may also exist in a gaseous or vapour phase and remain in that condition until detected and analysed. Even metals will have vapour pressures albeit very low at room temperatures allowing vapour molecules to be entrained into a wall jet and transported to the analysis facility. Other non-metallic solids also may yield molecules which are again detectable remotely. Liquids on a surface may also be detectable from vaporised molecules

vapour pressures from liquids generally being significantly higher than those for solids at the same temperature. Subject to compatibility with the surface incident free jets may be heated if necessary to promote removal of bound substances by softening, melting, evaporation or mechanical dispersal.

As mentioned earlier the monitoring system consists of two parts:- 1) a jet removal and transportation facility and:- 2) a detection and analysis facility for characterising substances transported from the surface. The detection and analysis facility may exist within a cell to which a proportion of the liberated substances is transported. Substances to be detected may be collected within the cell to be detected and analysed either in real time or subsequently. It is essential that facilities exist to preserve the free flow of air or gas through the cell otherwise Wis jet flow would be inhibited. Instead of collection of detected substances these may pass freely through the analysis cell and be detected in motion without accumulation.

For application involving removal of unwanted substances from surfaces for cleaning or decontamination purposes detection and analysis facilities are generally unnecessary - unless the liberated substances are of particular interest - and in this case liberated substances may be transported to a remote disposal facility possibly aided by a low pressure or vacuum system.

Numerous sensor methods are available to detect and characterise the physical, chemical or biological nature of liberated substances as well as their relative abundance. Such sensors may exist within the detection and analysis cell or in a position to which physical or

chemical data can be communicated from the analysis cell i.e. via optical fibres, radio, hard wire or other communication links. Various radiation types may be deployed for analysis of liberated substances including microwave, infrared, optical, ultraviolet, x rays and ultrasonics in order to stimulate or excite the substance under test its properties being deduced with appropriate detectors from the response to those exciters. For example particle size distribution may be deduced from optical scattering characteristics using narrow or broad band optical radiators. Alternatively chemical or biological species or properties may be deduced from fluorescent radiation generated with incident ultraviolet radiation possibly with the aid of chemical labels or from absorption by irradiated substances of specific radiation wavelengths. For example the presence of water on a surface may be deduced from infrared absorption bands by water vapour liberated from the surface. In circumstances where liberated substances are collected for analysis contacting chemical or microbiological analytical methods may prove appropriate.

The removal and transportation of substances from a surface may be made localised or extended according to the requirements and highly spatially specific if extremely small surface areas are to be interrogated.

It may be questioned why the removal of surface substances could not be implemented using vacuum or depressurisation methods as in a vacuum cleaner with these substances being transported to an analysis facility as dust is transported to a collection bag or the like using a vacuum cleaner. Such a procedure is limited in at least two respects:- firstly the possible depressurisation driving pressures cannot exceed one atmosphere and in practice

will be substantially less and secondly substances drawn into a vacuum system for analysis would not be specific to the surface unless the low pressure is applied directly to that surface implying physical contact by a vacuum facility. Otherwise not only will substance-liberating pressures be substantially lower than atmospheric but the collection system will not be specific to the surface and will draw in substances from the local environmental air.

In contrast the Wis jet method is by nature highly specific to the surface, can employ free jet pressures ranging from low to very high exceeding several atmospheres to remove solid substances which may be tightly bound to the surface - without the need for mechanical brushes necessary for vacuum cleaners - and can also provide highly localised removal of substances. In practice the Wis jet flow condition can be used solely for cleaning purposes with an analysis facility absent since substantially higher pressures can be generated than is possible with vacuum systems and by suitable configuration of the Wis jet the flow can be confined and entrained substances fed into a collection chamber for disposal. A suitable free jet configuration for this and indeed analytical purposes discussed above would be an annular jet directed onto the surface with or without a surrounding guard ring to reduce leakage outside the annulus. In this case the Wis jet would be axi-symmetric with the surrounding annular free jet and may pass with its entrained substances to a collection region for disposal (for cleaning purposes) or for substance characterisation as appropriate.

In order to transport a liberated substance from its surface regions to very remote regions the Wis jet may be fed into a vacuum system or pipe work leading to a remote dispersal or analysis facility.

Although free jets discussed so far have been cylindrical or annular alternative jet configurations and combinations including slot jets may be deployed according to the application. Further in some circumstances it may be advantageous to introduce into a free jet or jets dispersible substances to act as markers to increase detectability or to provide a solvent action to promote release of certain tightly bound substances on the surface for subsequent collection or analysis.

Specific embodiments of the invention will now be described by way of example only with reference to the accompanying drawing in which:-

Fig.1. shows a schematic diagram of a section through the axes of two cylindrical parallel free jets directed normally towards a surface forming a Wis jet moving away from the surface.

Fig.2. shows a schematic representation of flow velocity vectors within a section through a Wis jet on the line A-A in Fig.1

Fig.3. shows a schematic section of Wis jet formed from two free jets inclined to the surface normal.

Fig.4. shows a schematic representation of an axi-symmetric Wis jet formed from an annular free jet.

Fig.5. shows a section through a conical annular free jet producing an axial Wis jet.

Referring to Fig.1 this figure shows a section through the axes of two parallel cylindrical free jets 1 directed onto a surface 2 each forming respective axi-symmetric wall jets 3. If unimpeded each wall jet would flow radially away from the corresponding free jet axes along the surface with its boundary layer thickness and level of outer turbulence increasing with radial distance. In Fig.1. however each wall jet has opposing flow velocity components which interact on approach resulting in a flow away from the surface producing a so-called Wis jet 4. However during initial impact of each free jet onto the surface 2 and subsequent wall jet 3 flow relatively high viscous shear stresses may be generated in the inner jet boundary layer regions due to the steep flow velocity gradient in these regions and this combined with a high level of turbulence - not shown for clarity - associated with the outer regions of wall jets 3 provides an efficient means for flow interactions with the surface enabling loosely bound substances to be liberated from the surface 2 into the wall jet 3 and transported via the ensuing Wis jet 4 to a remote location where substance characterisation may be carried out using one of a number of physical or chemical analytical methods.

Fig.2 shows a Wis jet flow configuration 4 in a section on the line A-A in Fig.1. In this figure the Wis jet 4 extends in opposite - x+ve and x-ve - directions from the peak flow velocity vector 5 which is normal to the surface for identical free jets. This extended, non axi-symmetric Wis jet flow configuration possesses velocity vectors 6 diminishing in magnitude

and becoming progressively more inclined to the surface normal with increasing x+ve or x-ve displacement.

Analysis of substances liberated from the surface 2 and transported by means of the Wis jet away from the surface may be carried out in a sample chamber or cell - not shown in Fig.1 - supplied from the Wis jet. This chamber may possess a sensor system appropriate to the substance under test which may be physically or chemically based. For example to detect the presence of any liberated substances from the surface 2 which may constitute contamination of that surface 2 the sensor type may employ optical scattering using a high intensity light source irradiating the sample volume with information relating to the concentration and size distribution of liberated particles being deduced from the detection and analysis of scattered radiation. Other non-optical radiation types including ultrasonics may also be used for air borne particle detection and sizing measurement. To detect moisture microwave or infrared absorption methods may be employed. In order to deduce the chemical or biological nature of liberated substances whether existing in the solid, liquid or gaseous phase other sensor methods may prove more appropriate including infrared or optical absorption where certain chemical or biological species are detectable by absorption of specific wavelengths in incident radiation. Other methods for chemical or biological characterisation include excitation of fluorescence using ultraviolet incident radiation. In some circumstances X radiation may be employed for analysing irradiated material through X ray absorption or scattering.

As well as the above non-contacting methods using various types of ionising or non-ionising radiation other sensor types may be employed which may involve direct contact with liberated substances possibly involving chemical labelling to enhance detectability. In these and other circumstances it may prove convenient to collect or accumulate liberated substances in the sample chamber prior to analysis. In other circumstances analysis may be carried out in real time with air borne substances passing continuously through the sample chamber or cell volume.

In all cases to facilitate free flow of Wis jets efficient exhaust parts should exist at the outlet of the sample chamber to enable liberated substances to be discharged to the immediate environment or to some isolated disposal or collection facility as appropriate.

To increase wall jet and Wis jet flow rates for given free jet flow rates jets 7 may be inclined to the surface 2 normal see Fig.3. This will improve efficiencies for liberation and transportation of surface substances to be sensed remotely in a sample chamber. Analysis of data generated in the sample chamber using the appropriate sensor may be carried out locally within the chamber itself or may be transmitted to a remote signal processing unit using for example optical fibres, hard wire or radio communication links.

The Wis jet 4 flow configuration discussed so far was derived from two cylindrical free jets directed either normally to the surface 2 or inclined to the surface normal to improve Wis jet 4 flow rates and surface 2 substance liberation and transportation efficiencies. An alternative free jet, wall jet and Wis jet flow configuration which may possess some

improvements in operational efficiency and convenience, involves the generation of a single annular free jet 8 Fig.4 using a cylindrical chamber 9 with an annular slot or aperture 10 in the base 11. The roof 12 of the chamber 9 has an inlet port 13 coupled to which is a side port 14 to provide pressurised clean air or other environmentally compatible gas from a remote supply - not shown. Pressurised clean air or gas is forced into the chamber 9 through port 13 possibly involving baffles or the like to ensure even pressure distribution within the chamber 12 in order to produce uniform mean annular flow rates. The pressurised air or gas escapes from the chamber 9 - which in fact operates as a pressure chamber - through the annular aperture 10 forming an annular jet 8 directed towards the surface 2 under test. The aperture 10 may possess appropriate funnelling or a streamlined geometry to reduce eddy formation and thereby enhance flow rates. On reaching the target surface 2 the annular free jet 8 will form an axi-symmetric wall jet with radial velocity components 15 flowing unproductively outwards and components 16 productively inwards to form an axi-symmetric Wis jet 17 moving normally away from the surface towards the chamber 9 base 11. Axial with the base is a cylindrical exhaust port 18 this port 18 being isolated from the chamber 9 and providing a free exhaust route for the Wis jet by means of an outlet pipe 19. Situated within the port 18 is a sample region forming the sample chamber and containing sensors - not shown - to detect liberated substances from the surface 2. Physical data from a sensor system may be processed locally with processed data being transmitted to a remote site for observation or recording or the primary data from sensors may be communicated to a remote signal-processing unit (not shown) for analysis and recording.

Instead of generating a cylindrical annular free jet as shown in Fig.4 the aperture 10 in the pressure chamber 9 may be configured to produce a conical annular free jet configuration 20 Fig.5 to improve efficiencies in liberating and transporting substances by means of the Wis jet 17 through the sample chamber accommodated in the port 18.

The removal of freely bound substances from a target surface for remote analysis has been made possible using Wis jets formed from two cylindrical free jets or a single annular free jet. It will be understood that other jet configurations are equally applicable including slot jets and the most appropriate jet configuration will depend upon the geometry of the target surface and the area to be tested i.e. whether this is extensive or highly localised. In order to provide versatility of a jet formation and analysis system the pressure chamber 9 Fig.4 may possess different aperture geometries in the base 11 which may be deployed through valves according to requirements. Further for tightly bound surface substances it may be necessary to generate higher free jet flow rates to liberate the substances or a proportion of them and in such cases appropriate structural integrity requirements will be necessary to provide safe operation.

Although discussions so far have mainly related to liberation of surface substances for remote analysis using a Wis jet for transportation to an analysis location the method for removal of substances from a surface may as discussed briefly earlier be exploited for purely cleaning or decontamination purposes. In this case higher pressures than are possible with vacuum systems may be deployed for efficient removal of surface contaminants or dirt with liberated substances being transported via a Wis jet – preferably axi-symmetric - to a

disposal facility. In this case to enhance the efficiency of removal of liberated substances to a disposal site the Wis jet may be coupled into a low pressure or vacuum system leading to a disposal chamber or facility.

It will be appreciated that the use of a Wis jet and its associated wall jet and free jet flow configurations may be used in place of mechanical swabs frequently used for removing surface substances for remote analysis. The benefit of the Wis jet method results from the avoidance of physical contact with the surface under test.

Similarly mechanical brushes generally employed in commercially available vacuum cleaners to liberate debris for removal by a vacuum system may be replaced by a Wis jet and associated jets system thereby avoiding mechanical contact with a surface or membrane and enabling delicate or fragile surfaces to be cleaned without damage or disturbance.

Claims

1) A method for removing for disposal and/or detection and analysis removable substances adhered to a surface involving the steps of directing one or more free jets onto the surface to create respective wall jets flowing along the surface in order to liberate and entrain removable substances on the surface into the wall jet or jets and thereby transport them away from the surface by means of a retro-flow configuration - herein referred to as a WIS Jet - which moves away from the surface as a result of the interaction of opposing wall jet flow velocity components said substances being transported to a region away from the surface for disposal or detection and analysis this latter involving one of a number of sensors appropriate to the nature of the liberated substance or substances.

2) A method according to claim 1 wherein two axially displaced parallel cylindrical free jets are directed normally towards the target surface.

3) A method according to claim 1 wherein two axially displaced axially converging cylindrical free jets are directed towards a target surface each jet being angularly displaced from the surface normal such that a finite separation exists between the jets on surface impingement.

4) A method according to claim 1 wherein an annular parallel sided free jet is directed normally towards the target surface.

5) A method according to claim 1 wherein an annular converging free jet is directed towards the target surface with the jet axis normal to the surface and the annular radius finite as the jet impinges onto the surface.

6) A method according to claims 2 and 3 wherein opposing wall jet radial flow components from corresponding free jet impingement on the surface create a retro-flow configuration symmetrical about the line joining the free jet axes.

7) A method according to claims 4 and 5 wherein opposing wall jet radial flow components from normal impingement on the surface of an annular free jet create an axi symmetric retro-flow configuration with its axis coincident with that of the annular free jet.

8) A method according to any of the claims 1 to 7 wherein at least a portion of said retro-flow passes to a region containing the means for detecting and analysing and/or collecting and disposing of substances liberated from a target surface.

9) A method according to claim 8 wherein the region for liberated transported substance detection and analysis and/or disposal contains the means for facilitating free flow of the retro-flow carrier gas to that region.

10) A method according to any of the claims 1, 4, 5, 7, 8 and 9 when claims 8 and 9 are dependant upon claims 1,4,5 and 7 wherein one or more free jets are produced by forcing a gas into a pressure chamber through an inlet pipe said pressure chamber which may contain baffles or the like to promote even pressure distribution containing one or more orifices through which contained gas escapes forming said free jet or jets.

11) A method according to claim 10 wherein there exists an orifice which is annular thereby producing an annular free jet.

12) A method according to claim 11 wherein the annular orifice is shaped to reduce resistance to flow of escaping jet forming gas.

13) A method according to claims 11 or 12 wherein the geometry of the orifice is annular and contoured to produce a converging annular jet.

14) A method according to claim 10 wherein the orifice or orifices in the pressure chamber may exist with the same or different geometries and may possess associated valves enabling different numbers of jets , jet types and geometrical configurations to be produced and selected.

15) A method according to claim 10 wherein the pressure chamber contains a cell for accommodating the means for detecting and analysing substances liberated from the target surface said cell being isolated from higher pressure surrounding gas within the pressure chamber.

16) A method according to Claim 15 wherein the cell exists within a port isolated from surrounding higher pressure gas within the pressure chamber and through which retro -flow carrier gas may pass prior to exhausting from the pressure chamber through an outlet pipe after detection and characterisation of liberated substances within the cell.

17) A method according to claims 15 or 16 wherein a proportion of substances removed from a target surface and transported to the cell by means of associated wall jet and retro-flow are collected or accumulated within the cell to be detected and analysed.

18) A method according to any of the previous claims wherein analysis occurs in real time.

19) A method according to any of the claims 1 to 17 wherein analysis is delayed.

20) A method according to any of the claims 1 to 14, 18 and 19 wherein transported substances may be detected and analysed without collection within the cell.

21) A method according to any of the claims 1 to 20 wherein entrained substances from the target surface may be transported to a region for detection and analysis or disposal or both using means additional to a retro-flow process.

22) A method according to claim 21 wherein transportation of entrained substances may be aided by means of a low pressure or vacuum system.

23) A method according to any of the claims 4, 5 and 7 to 22 wherein an annular free jet may have an associated guard ring.

24) A method according to any of the previous claims wherein detection and analysis of transported substances may involve physical sensors.

25) A method according to any of the claims 1 to 23 wherein detection and analysis of transported substances may involve chemical sensors.

26) A method according to any of the claims 1 to 23 wherein detection and analysis of transported substances may involve biological sensors.

27) A method according to any of the claims 1 to 26 wherein surface bound substances to be disposed of or detected and analysed may exist in a solid, liquid or vapour phase on the target surface but may undergo phase transformation prior to detection and analysis or disposal.

28) A method according to any of the previous claims wherein free jets are heated

29) A method according to any of the claims 1 to 28 wherein substances may be incorporated into free jets to aid removal of surface substances

30) A method according to any of the previous claims wherein substances may be incorporated into free jets to aid detection and analysis of substances liberated from surfaces.

31) A method according to claim 29 wherein solvents may be incorporated into free jets to aid release of tightly bound substances.

32) A method according to any of the previous claims wherein the sensor means for detecting and analysing substances liberated from a target surface employs radiation.

33) A method according to claim 32 wherein the radiation is microwaves.

34) A method according to claim 32 wherein the radiation is infra red.

35) A method according to claim 32 wherein the radiation is optical.

36) A method according to claim 32 wherein the radiation is ultra violet.

37) A method according to claim 32 wherein the radiation is X rays.

38) A method according to claim 32 wherein the radiation is ultrasonic.

39) A method according to any of the claims 32 to 38 wherein compatible radiation detectors are employed.

40) A method according to any of the previous claims wherein physical, chemical or biological data as appropriate may be transmitted from the data source within an analysis cell or elsewhere to a remote compatible sensor using communication links including optical fibres, radio or hard wire.

41) A method according to claim 35 wherein particle size distribution of liberated and transported substances may be deduced using optical scattering.

42) A method according to claim 36 wherein chemical or biological species and properties may be deduced from ultra violet induced fluorescence.

43) A method according to claim 42 wherein chemical labels may be employed.

44) A method according to claim 34 wherein analysis of liberated substances may exploit infra red absorption.

45) A method according to any of the previous claims wherein the target surface area to be monitored for adhered substances may be localised thereby providing high spatial specificity.

46) A method according to any of the claims 1 to 44 wherein the target surface area to be monitored for adhered substances may be extended.

47) A method according to any of the claims 24 to 26 and 32 to 44 wherein electronic processing of physical, chemical or biological data from sensors or detectors may involve recording of primary or processed data.

48) A method substantially as herein before described with reference to any one of the accompanying drawings.

49) Apparatus for removing for disposal and/or detection and analysis removable substances adhered to a surface comprising means for producing and directing one or more free jets onto a target surface to form one or more corresponding wall jets on the surface in order to liberate through viscous drag forces removable substances from the surface and entrain said substances into said wall jets or jets and thereby transport them to a region remote from the surface by

means of wall jet flow and a retro-flow configuration - herein referred to as a WIS jet - which moves away from the surface as a result of interaction of opposing wall jet flow components said remote region possessing the means for either collection or disposal of entrained surface substances and/or the means for detection and analysis of said entrained substances.

50) Apparatus according to claim 49 wherein two axially displaced parallel cylindrical free jets are produced.

51) Apparatus according to claim 49 wherein two axially displaced axially converging cylindrical free jets are produced but having a finite separation as they impinge on the target surface.

52) Apparatus according to claim 49 wherein a single parallel sided annular free jet is produced.

53) Apparatus according to claim 49 wherein a single annular converging free jet is produced yielding a finite annular radius on surface impingement when the jet axis is directed normally towards the surface.

54) Apparatus according to claims 50 or 51 wherein the resultant wall jets from corresponding cylindrical free jet impingement on a target surface create a retro-flow condition symmetrical about the line joining the free jet axes.

55) Apparatus according to claims 52 or 53 wherein opposing wall jet radial flow components resulting from normal impingement of an annular free jet on a target surface create an axi symmetric retro-flow configuration with its axis coincident with that of the annular free jet.

56) Apparatus according to claims 49 to 55 wherein at least a proportion of the retro-flow transporting substances liberated from a target surface enters a region containing the means for detection and analysis and or collection and disposal of substances liberated from a target surface.

57) Apparatus according to claim 56 wherein means exist to ensure free flow of retro-flow carrier gas transporting surface liberated substances to a detection and analysis and or disposal region.

58) Apparatus according to any of the claims 49, 52, 53 and 55 and 56 and 57 when claims 56 and 57 are dependant upon claims 49, 52, 53 and 55 wherein means are provided to force a gas into a pressure chamber through an inlet pipe said pressure chamber which may have baffles or the like to promote even pressure distribution containing means for generating one or more free jets by allowing internal pressurised gas to escape through one or more orifices.

59) Apparatus according to claim 58 wherein an annular free jet is produced by an associated annular orifice.

60) Apparatus according to claim 59 wherein the annular orifice is streamlined to reduce flow resistance of escaping gas.

61) Apparatus according to claims 59 or 60 wherein the annular orifice geometry is contoured to produce a converging annular jet.

62) Apparatus according to claim 58 wherein one or more jet forming orifices in the pressure vessel may exist with the same or different geometries and may possess associated valves enabling different numbers of jets, jet types and geometrical configurations to be produced and selected.

63) Apparatus according to claim 58 wherein the pressure chamber contains a cell for accommodating the means for detecting and analysing substances liberated from the target surface and transported to said cell by associated retro-flow said cell being isolated from surrounding higher gas pressure within the pressure chamber.

64) Apparatus according to claim 63 wherein the cell exists within a port isolated from surrounding higher pressure gas within the pressure chamber and through which retro-flow carrier gas may pass prior to exhausting from the pressure chamber through an outlet pipe after detection and analysis of liberated substances within the cell.

65) Apparatus according to claims 63 or 64 wherein a proportion of substances liberated from the target surface and transported to the cell by means of retro-flow carrier gas are collected and accumulated within the cell for detection and analysis.

66) Apparatus according to any of the claims 49 to 65 wherein detection and analysis occurs in real time.

67) Apparatus according to any of the claims 49 to 65 wherein detection and analysis is delayed.

68) Apparatus according to any of the claims 49 to 62, 66 or 67 wherein transported substances may be detected and analysed without collection within a cell.

69) Apparatus according to any of the claims 49 to 68 wherein means are provided to transport substances liberated from a target surface to a region for detection and analysis or disposal or both using means in addition to a retro-flow process.

70)Apparatus according to claim 69 wherein transportation of entrained substances may be aided by means of a low pressure or vacuum system.

71) Apparatus according to any of the claims 52, 53, and 55 to 70 wherein an annular free jet may have an associated guard ring.

72) Apparatus according to any of the claims 49 to 71 wherein detection and analysis of transported substances may involve physical sensors

73) Apparatus according to any of the claims 49 to 71 wherein detection and analysis of transported substances may involve chemical sensors.

74) Apparatus according to any of the claims 49 to 71 wherein detection and analysis of transported substances may involve biological sensors.

75) Apparatus according to any of the claims 49 to 74 wherein surface bound substances to be disposed of or detected and analysed may exist in a sold, liquid or vapour phase on the target surface but may undergo phase transformation prior to disposal or detection and analysis.

76) Apparatus according to any of the claims 49 to 75 wherein free jets are heated.

77) Apparatus according to any of the claims 49 to 76 wherein substances may be incorporated into free jets to aid removal of surface substances.

78) Apparatus according to any of the claims 49 to 77 wherein substances may be incorporated into free jets to aid detection of transported substances.

79) Apparatus according to claim 77 wherein solvents may be incorporated into free jets to aid release of tightly bound substances.

80) Apparatus according to any of the previous claims wherein the sensor means for detecting and analysing substances liberated from a target surface employs radiation.

81) Apparatus according to claim 80 wherein the radiation is microwave.

82) Apparatus according to claim 80 wherein the radiation is infra red.

83) Apparatus according to claim 80 wherein the radiation is optical.

84) Apparatus according to claim 80 wherein the radiation is ultraviolet.

85) Apparatus according to claim 80 wherein the radiation is X rays.

86) Apparatus according to claim 80 wherein the radiation is ultrasonic.

87) Apparatus according to any of the claims 80 to 86 wherein compatible radiation detectors are employed.

88) Apparatus according to any of the claims 49 to 87 wherein physical, chemical or biological data as appropriate may be transmitted from the data source within an analysis cell or elsewhere to a remote compatible sensor using communication links including optical fibres, radio or hard wire.

89) Apparatus according to claim 83 wherein particle size distribution of liberated and transported substances may be deduced using optical scattering.

90) Apparatus according to claim 84 wherein chemical or biological species and properties may be deduced from ultraviolet induced fluorescence.

91) Apparatus according to claim 84 wherein chemical labels may be employed.

92) Apparatus according to claim 82 wherein analysis of liberated substances may exploit infra red radiation.

93) Apparatus according to any of the claims 49 to 92 wherein the target surface area to be monitored for adhered substances may be localised thereby providing high spatial specificity.

94) Apparatus according to any of the claims 49 to 92 wherein the target area to be monitored for adhered substances may be extended.

95) Apparatus according to any of the claims 72 to 74 and 80 to 92 wherein electronic processing of physical, chemical or biological data from sensors or detectors may involve recording of primary or processed data.

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Claims searched:	1-95	**Date of search:**	23 October 2002

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Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.T): A4F; F2N

Int Cl (Ed.7): B08B 5/00 5/02; B05B 1/00 /104 1/06; G01N 1/02

Other: Online:- WPI, EPODOC, PAJ

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
A	EP 0224034 A1 Weiss - see figs 1 & 2	

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
		E	Patent document published on or after, but with priority date earlier than, the filing date of this application.
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